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Sprint

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July 11, 2000

VIA HAND DELIVERY

Ms. Magalie Roman Salas, Secretary
Federal Communications Commission
The Portals, 445 12th Street, S.W.
Room TW-B204
Washington, D.C. 20554

Re: ***Ex Parte* Notification**
Revisions of the Commission's Rules To Ensure Compatibility with Enhanced 911 Emergency Calling Systems, CC Docket No. 94-102

Dear Ms. Salas:

Pursuant to section 1.1206(a)(1) of the Commission's rules, Sprint PCS is filing two copies of the attached letter and technical reports prepared by Lucent Technologies and QUALCOMM, Inc. concerning the above referenced proceeding. The letter is directed to Thomas J. Sugrue, Chief of the FCC's Wireless Telecommunications Bureau and offers the technical reports in support of Sprint PCS' December 6, 1999, Petition for Reconsideration filed in the above referenced docket.

The reports, one prepared by Lucent Technologies and one prepared by QUALCOMM, Inc., reflect the accuracy of the Advanced Forward Link Triangulation ("AFLT") technology discussed in the Sprint PCS Petition.

Please contact the undersigned with any questions.

Sincerely,

Jonathan M. Chambers

Attachments: QUALCOMM, Inc. and Lucent Technologies AFLT reports
cc. Blaise Scinto, Deputy Chief, Policy Division, Wireless Telecommunications Bureau
Daniel Grosh, Senior Attorney, Policy Division, Wireless Telecommunications Bureau

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July 11, 2000

Thomas J. Sugrue, Chief
Wireless Telecommunications Bureau
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C. 20554

Re: Revisions of the Commission's Rules To Ensure Compatibility with Enhanced 911 Emergency Calling Systems, CC Docket No. 94-102

Dear Mr. Sugrue:

On December 6, 1999, Sprint Spectrum L.P., d/b/a Sprint PCS ("Sprint PCS") filed a Petition for Reconsideration in the above referenced docket. Sprint PCS sought Commission review of Sprint PCS' proposed hybrid solution for compliance with the obligations of 47 C.F.R. §20.18.

In support of its Petition for Reconsideration, Sprint PCS has continued to participate in tests of the location technology referenced in its filing. Attached to this letter are two recent reports, one prepared by Lucent Technologies and one prepared by QUALCOMM, Inc., which reflect the accuracy of the Advanced Forward Link Triangulation ("AFLT") technology discussed in the Sprint PCS Petition.

Please contact the undersigned with any questions.

Respectfully submitted,

Jonathan M. Chambers

Attachments: QUALCOMM, Inc. and Lucent Technologies AFLT reports
cc. Blaise Scinto, Deputy Chief, Policy Division, Wireless Telecommunications Bureau
Daniel Grosh, Senior Attorney, Policy Division, Wireless Telecommunications Bureau

AFLT & EFLT 1 sigma error (67%)

Scenario 1: stationary outdoor with clear view of sky (Hanover High School) 5/31

No averaging

AFLT

Total 1 sigma	260m	72 fixes	100%
1 BS	263m	48 fixes	66.7%
2 BS	101m	21 fixes	29.2%
3 BS	66m	3 fixes	4.2%

5 Point Averaging

Total 1 sigma	259m

Scenario 1: stationary outdoor with clear view of sky (Hanover High School) 6/7

No Averaging

AFLT

Total 1 sigma	297m	115 fixes	100%
1 BS	360m	22 fixes	19.1%
2 BS	254m	57 fixes	49.6%
3 BS	83m	36 fixes	31.3%

EFLT (Mobildm)

Total 1 sigma	159m	198 tixes	100%
1 BS	n/a	2 fixes	1%
2 BS	454m	35 fixes	17.7%
3 BS	163m	159 fixes	80.3%

EFLT (Viper)

Total 1 sigma	163m	892 fixes	100%
1 BS	315m	126 fixes	14.1%
2 BS	198m	338 fixes	37.9%
3 BS	126m	428 fixes	48.0%

5 Point Averaging

AFLT

Total 1 sigma	182m

EFLT (Mobildm)

Total 1 sigma	110m

EFLT (Viper)

Total 1 sigma	106m

Scenario 2: stationary outdoor with partial blockage of sky by 3 story building (Lucent) 5/31

No averaging

AFLT

Total 1 sigma	820m	124 fixes	100%
1 BS	820m	101 fixes	81.5%
2 BS	160m	23 fixes	18.5%

5 Point Averaging

Total 1 sigma	816m

Scenario 2: stationary outdoor with partial blockage of sky by 3 story building far from base stations (Lucent) 6/6

No Averaging

AFLT

Total 1 sigma	820m	101 fixes	100%
1 BS	822m	72 fixes	71.3%
2 BS	127m	29 fixes	28.7%

EFLT (Mobildm)

Total 1 sigma	188m	64 fixes	100%
1 BS	n/a	4 fixes	6.3%
2 BS	195m	56 fixes	87.5%
3 BS	n/a	4 fixes	6.3%

EFLT (Viper)

Total 1 sigma	465m	327 fixes	100%
1 BS	838m	87 fixes	26.6%
2 BS	329m	240 fixes	73.4%

5 Point Averaging

AFLT

Total 1 sigma	818m

EFLT (Mobildm)

Total 1 sigma	217m

EFLT (Viper)

Total 1 sigma	444m

Scenario 3: stationary outdoor with clear view of sky and close to one base station (GPU) 6/13

No Averaging

AFLT

Total 1 sigma	29m	77 Fixes	100%
1 BS	29m	77 Fixes	100%

5 Point Averaging

EFLT (Mobildm)

Total 1 sigma	55m	84 Fixes	100%
1 BS	55m	84 Fixes	100%

5 Point Averaging

AFLT

Total 1 sigma	29m

5 Point Averaging

AFLT

Total 1 sigma	51m

Comments and Caveats

1. Using the off the shelf Qualcomm handset, EFLT consistently saw more base stations than the Qualcomm AFLT prototype.
We expected the AFLT phone to see more base stations, and this may indicate fine tuning is required in the AFLT prototype mobile software.

2. The AFLT 2 & 3 base station cases outperformed the EFLT 2 & 3 base stations

3. The AFLT mobile from Qualcomm is an unsupported prototype

4. The AFLT mobile is not as sensitive as commercial, off the shelf handsets
(i.e. sees fewer base stations and may make measurement errors as a result)

5. The RTD data used in the AFLT calculations comes from RF Calltrace. Calltrace generates data points every 2 seconds.
As a result, RTD data from Calltrace is not the quality it will be in the commercial product and may have impacted the results.

6. AFLT and Viper EFLT did not perform as expected with 1 base station. This is inconsistent with our expectations and we will be analyzing the data further to provide an explanation.

7. The total number of samples for specific cases is small (a function of the AFLT prototype mobile's current capability), and more data is required before extrapolating these results to other scenarios and predicting overall performance.

8. In some cases 5 point averaging was ineffective because the 1 base station case errors overwhelmed the 2 and 3 base station results.

9. Additional build-out of base stations will further enhance performance, particularly in rural and highway environments.

QUALCOMM®
CDMA Technologies

Field Measurements for CDMA Positioning

80-V1791-1 Rev. X1

June 30, 2000

QUALCOMM Incorporated
5775 Morehouse Dr.
San Diego, CA 92121-1714
U.S.A.

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1 Introduction

This document summarizes field data used for CDMA positioning (positioning based on the use of CDMA IS-95 based data). The data was collected in San Diego, with representatives from Sprint, between June 20 and June 22, 2000. Forward link pilot information was logged and some other measurements were assumed and simulated as described in the following.

1.1 Test Environment and Locations

- Locations within approximately 3 km radius from the Qualcomm campus.
- Suburban hilly environment.
- Sprint PCS commercial network (1900MHz), with **relatively small distance between BTSs** (see figure below).
- Indoor, outdoor and one limited moving scenario.
- Measurements with and without the "salt head". Purpose is to mimic the effect of the human head.

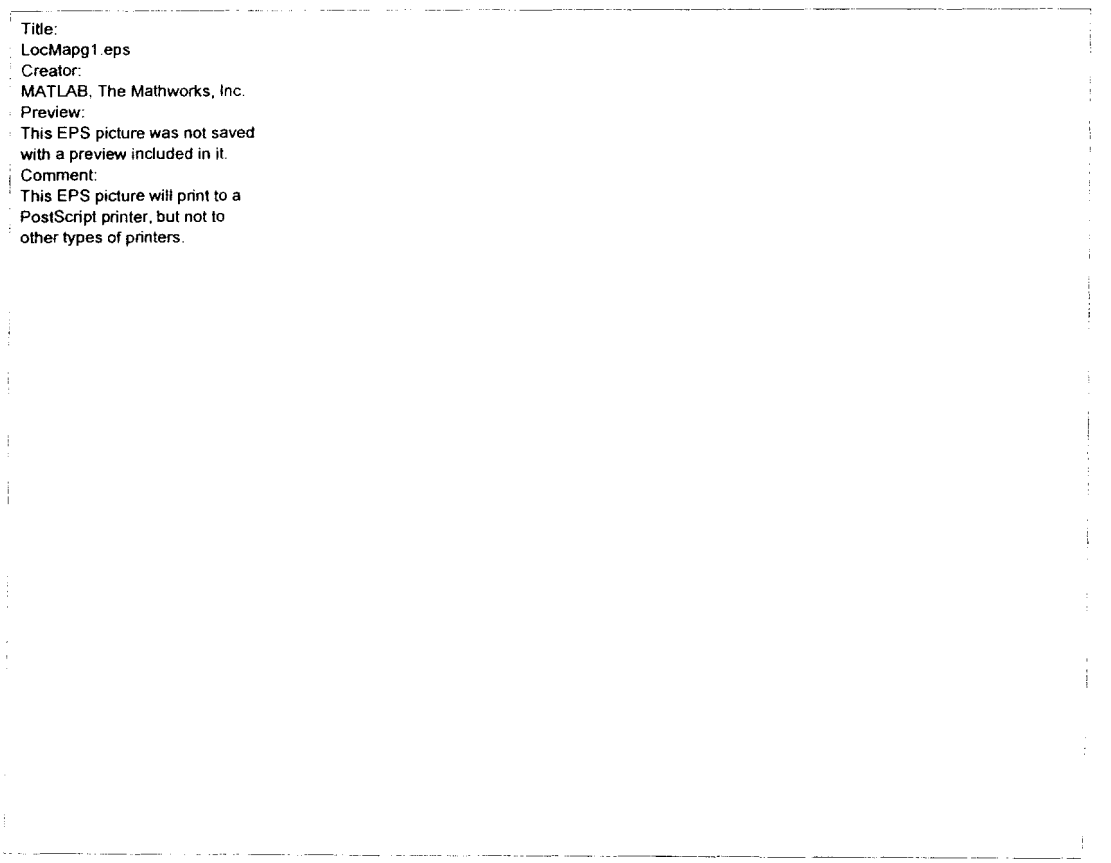

Figure 1 BTS and test locations

1.2 Equipment and Logging Process

- Prior BTS calibration.
- I and Q data logged from a commercial Qualcomm QCP®-1960 mobile phone.
- GPS / surveyed positions for ground truth, using WGS-84 model.
- Post processing of the data.
- No RTD measurements available.

1.3 Results Applicability

Caution must be used when considering the results:

- Results were obtained in **suburban scenarios**. Urban scenarios and rural scenarios may show **significantly different results** due to different propagation characteristics and/or large cell sectors and/or poor geometry.
- BTS visibility could be different in other environments.
- Limited number of locations will impact statistical significance.
- Number of measurements per location is not enough in order to get 95% statistics. Based on availability vs accuracy results, the 2 sigma (95%) error is expected to be far greater than the 1 sigma error statistics given here.
- Results were obtained in a network where there are not issues associated with repeaters. **Repeaters could cause serious problems**, reducing the number of usable measurements and their accuracy.
- Results depend on network issues like neighbor list size and search window size. Larger neighbor lists and search window sizes will increase the time to fix and/or reduce the performance. For a fixed time budget, larger search windows and neighbor list can affect the performance due to less time being allocated to searching each of the PNs.
- 3D and velocity solutions are not practically achievable with AFLT based solutions.
- Data must be considered in light of the assumptions detailed in the following chapter.

2 Data Analyses and Assumptions

2.1 General Assumptions

2.1.1 Searcher Outputs

- Searcher able to produce the on-time, early and late accumulated energies for peak sampled at Chipx2 to enable interpolation to better accuracy (as supported by MSM™-3300, being considered for the MSM™-5105, but not supported by the MSM™-3100). Data *assumes* the same noisy samples for this interpolation (which is not always the case).

2.1.2 Time to Fix and Number of Search Cycles

- Assumption of ~1.4 seconds for 16x searcher to complete a search cycle for about 24 PNs, with search window of 40 chips (24 PNs x 3 searches per window x 0.02 sec per search). The number of PNs and window sizes correspond roughly to what was logged from PN 348.
- Data logged (pilot search time) is over 5.5 seconds.
- Searcher performs 4 search cycles over the PN list.
- Note that larger search window sizes and larger PN lists, would increase the search cycle time which would **increase** the time to fix and/or **degrade** performance. Longer searches will also require more power consumption.

2.1.3 PNs Searched

- PNs searched are all the BTSs that we have verified in the area. Some of our results may be **optimistic** as we could be using PNs that are not in the neighbor list. We can correct this analyses if we get a neighbor list for each PN.

2.2 Solution Assumptions

We provide 3 sets of solutions as described below. We only do 2D positioning.

2.2.1 AFLT Only Solution

- This solution assumes only time difference of arrival (TDOA) measurements. We thus have to see at least 3 BTS locations to get a fix.
- The solution solves for ambiguity.
- Bad results are discarded based on integrity criteria at the expense of lower availability, but with advantage of smaller 2D error. The trade-off used here, was based on the set-point used for analyses of previous data collected in this area.

2.2.2 Solution with Fake RTD

- This solution adds one RTD measurement to the previous set of TDOA measurements. We thus only have to see 2 BTS locations to get a fix.
- The RTD is taken to the BTS with the strongest measured pilot strength.
- The one way delay (OWD) measurement (=RTD/2), is take to be the true distance between the MS and the BTS + the absolute value of a Gaussian variable. The two-sided Gaussian noise variable had a STD of 100 meters.
- Solution doesn't solve for ambiguity. We start the LMS from the correct position, which could improve the results if we are unable to solve the ambiguity problem.
- Some results have been discarded based on integrity criteria.

2.2.3 Estimated Solution Including Fake RTD and AOA Estimate

- Enables us to always give an estimate of location for the cases that we are not able solve with the TDOA and OWD measurements. Thus we always get a location estimate.
- RTD and AOA estimate is taken from the strongest pilot only.
- Estimate technique is the same for all the PNs / BTSs, disregarding real network information (e.g., sector orientation).
- Estimation assumes an angle of arrival uncertainty region, and error is radius of circle centered on the arc and covering 67% of the arc. The radius of the arc is determined by the fake RTD measurement. This estimation solution gives an error that is linear with the distance to the BTS, and thus gives **significant error** for large sectors.

2.3 Reading the Results Tables

- In the next sections we have the results for the different locations. For each location we have two cases: without the salt head appearing in the upper part of the table, and the results with the salt head appearing in the lower half of the table.
- We have the results for 3 different kinds of solutions:

  1. TDOA only.
  2. TDOA + fake RTD.
  3. TDOA, fake RTD + AOA estimation.

  The assumptions, behind these solutions, are given in Section 2.2.
- For each of the 3 kinds of solutions and two cases we have 3 types of results:

  1. Yield – the percentage of times that we are able to get a positioning solution with the given method.

2. Mean Error [m] – the average error, in meters, for the **cases that we got a positioning solution** with the given method. Note that the mean error is not a 50% error value but an average of successful fixes.

3. 1 Sigma (67%) Error [m] – the error value in meters below which are 67% of the **cases for which we got a positioning solution**. Thus the standard 1 sigma statistics are only applicable for the cases where we have 100% positioning solution yield, such as the last column in the results tables. For the cases where yield is less than 100%, 1 sigma statistic does not represent a 67 error percentile. For these cases, the percentile is written in brackets next to the value (in meters) of the 1 sigma statistic.

3 Outdoor Locations

All the outdoor locations were done with the phone in a van with the door open on one side. For each location 2 sets of test were done, one without and one with the "salt head" close to the phone. Reference location is given in LLH, latitude (in degrees and minutes), longitude (in degrees and minutes) and height (in meters) coordinates using WGS-84.

The location number corresponds to the number in Figure 1.

3.1 AA Parking Lot

Reference location (LLH): 32° 53.4564' N, 117° 13.4314' W, 97.8 m.

Location description: in van near tree and 4 story building several meters away to the north.

Location identification: #3, 1205-7 and 1225-7, 20 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	96.7%	100%	**100%**
	Mean Error [m]	160.7	171.5	**171.5**
	1 Sigma (67%) Error [m]	213.6 (65%)	231.7	**231.7**
With Salt Head 30 samples	Yield	93.3%	100%	**100%**
	Mean Error [m]	176	144.4	**144.4**
	1 Sigma (67%) Error [m]	208.5 (63%)	143.8	**143.8**

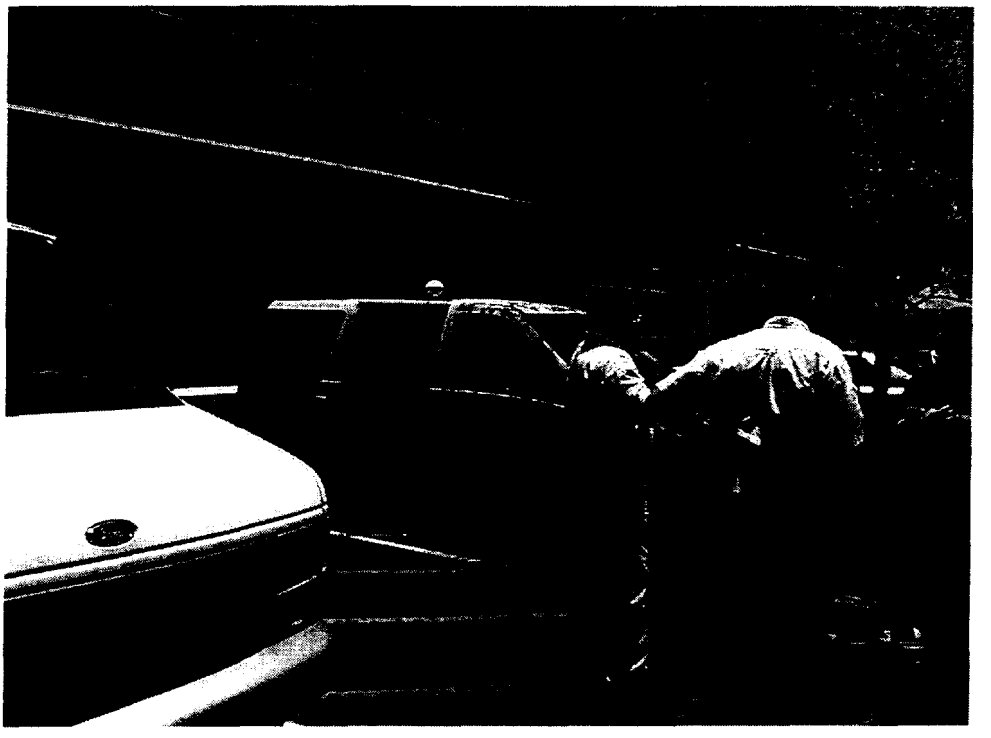

Figure 2 Location #3

3.2 Campus Point Drive

Reference location (LLH): 32° 53.0418' N, 117° 13.2181' W, 105.5 m.

Location description: in van, lots of trees close on hill along one side of van.

Location identification: #4, 1350-2 and 1415-7, 20 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 20 samples	Yield	0%	40%	**100%**
	Mean Error [m]	-	184.7	**284.6**
	1 Sigma (67%) Error [m]	-	250.0 (27%)	**339.6**
With Salt Head 30 samples	Yield	0%	70%	**100%**
	Mean Error [m]	-	146.7	**202.2**
	1 Sigma (67%) Error [m]	-	175.8 (47%)	**303.7**

Note: due to a problem with the logging mechanism, only 20 sets of samples were logged for the cse without the salt head.

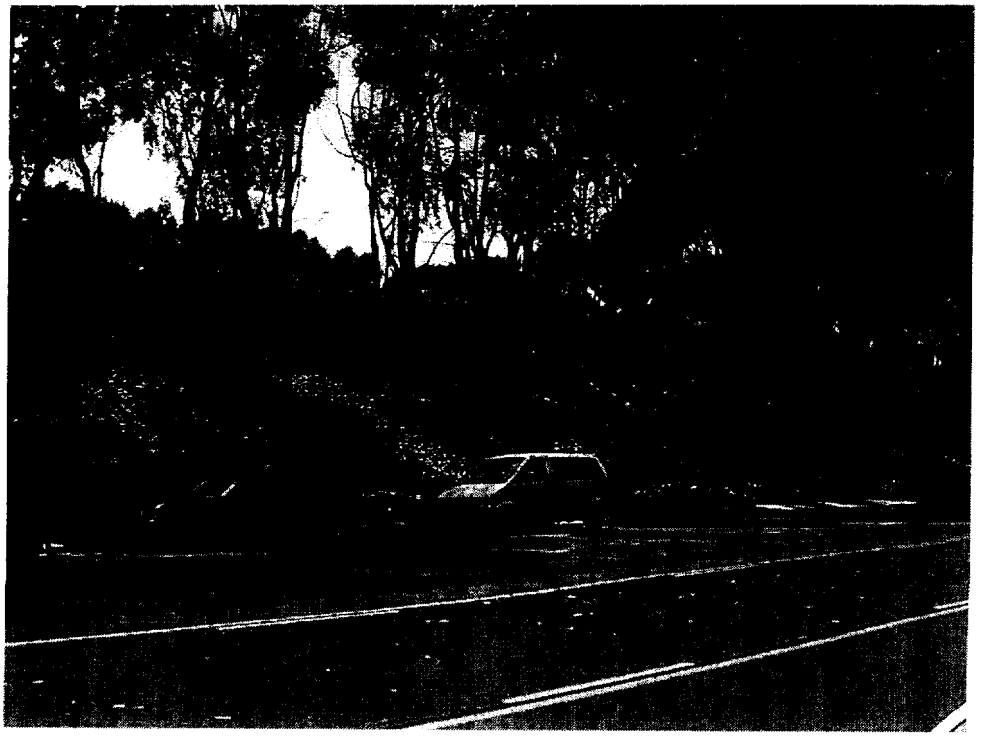

Figure 3 Location #4

3.3 Apartment Complex on Genesse

Reference location (LLH): 32° 52.6883' N, 117° 12.8285' W, 114.2 m.

Location description: in van, near car sheds and trees, close to Genesse with lots of traffic.

Location identification: #5, 1455-7 and 1515-7, 20 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	100%	96.7%	**100%**
	Mean Error [m]	167.4	119.7	**146.3**
	1 Sigma (67%) Error [m]	176.1	130.6 (65%)	**131.8**
With Salt Head 30 samples	Yield	66.7%	100%	**100%**
	Mean Error [m]	234.2	208.8	**208.8**
	1 Sigma (67%) Error [m]	352.8 (45%)	299.3	**299.3**

Figure 4 Location #5

3.4 Executive Square Drive Way

Reference location (LLH): 32° 52.4300' N, 117° 12.8033' W, 113.0 m.

Location description: in van, tall buildings in vicinity (50-75 meters away) and trees.

Location identification: #6, 1545-7 and 1605-7, 20 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	60%	63.3%	**100%**
	Mean Error [m]	89.8	87.5	**378.1**
	1 Sigma (67%) Error [m]	114.8 (40%)	103.7 (42%)	**750.4**
With Salt Head 30 samples	Yield	100%	100%	**100%**
	Mean Error [m]	94.4	86.4	**122.8**
	1 Sigma (67%) Error [m]	96.1	92.1	**92.2**

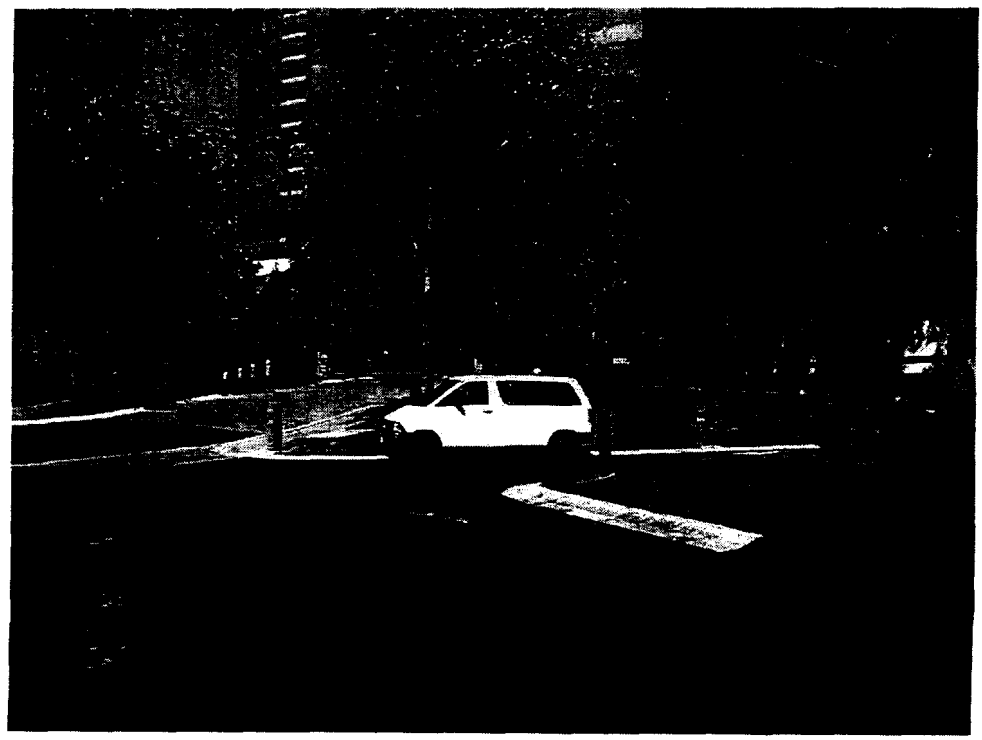

Figure 5 Location #6

3.5 Sorrento Valley Food Court

Reference location (LLH): 32° 53.6023' N, 117° 12.1935' W, 68.9 m.

Location description: shopping plaza, in van, single story buildings on 3 sides, tall buildings on one side 75-100 meters away, and trees.

Location identification: #7, 0945-7 and 1005-7, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	0%	16.7%	**100%**
	Mean Error [m]	-	279.9	**224.6**
	1 Sigma (67%) Error [m]	-	326.7 (11%)	**241.4**
With Salt Head 30 samples	Yield	0%	0%	**100%**
	Mean Error [m]	-	-	**221.8**
	1 Sigma (67%) Error [m]	-	-	**230.3**

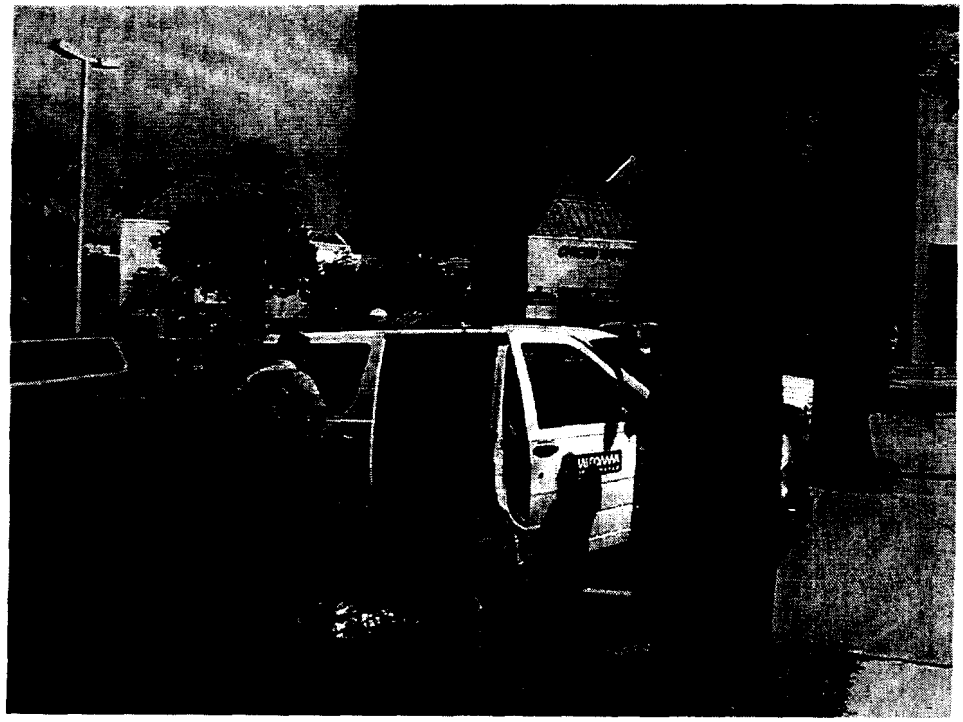

Figure 6 Location #7

3.6 Al Parking Lot

Reference location (LLH): 32° 54.0441' N, 117° 11.8569' W, 92.4 m.

Location description: in van, small buildings, foliage on hill to one side.

Location identification: #11, 1310-2 and 1320-2, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	63.3%	100%	**100%**
	Mean Error [m]	343.4	170.7	**170.7**
	1 Sigma (67%) Error [m]	181.4 (42%)	157	**157**
With Salt Head 30 samples	Yield	43.3%	93.3%	**100%**
	Mean Error [m]	476.7	128.5	**372.5**
	1 Sigma (67%) Error [m]	432.3 (29%)	135.9 (63%)	**156.3**

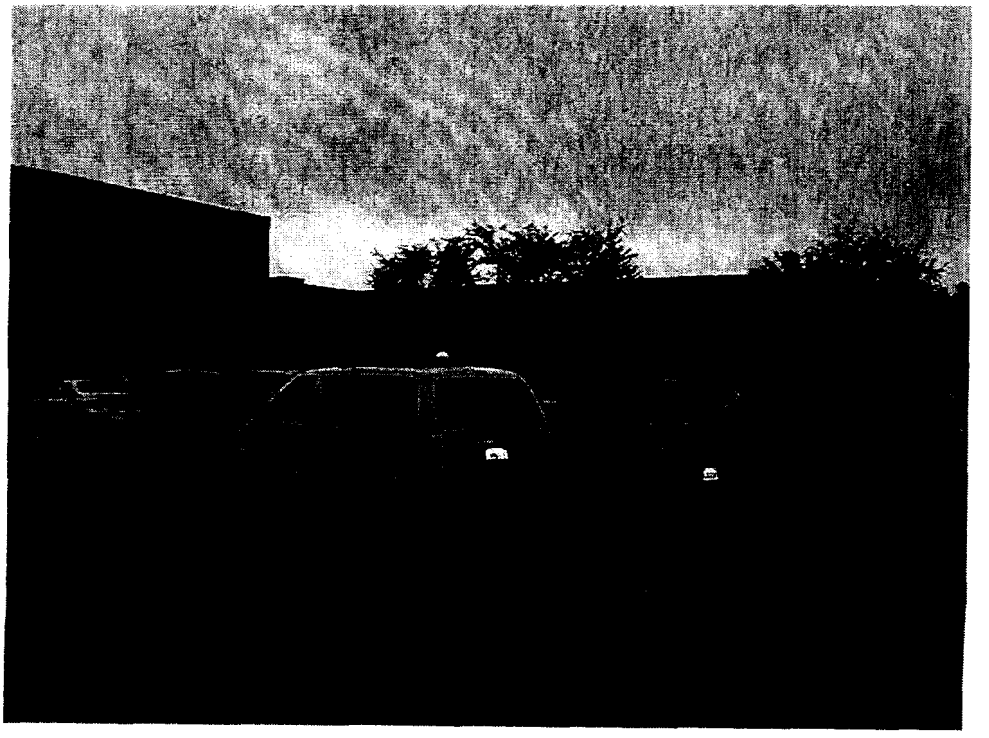

Figure 7 Location #11

3.7 AF Parking Lot

Reference location (LLH): 32° 54.0113' N, 117° 12.0809' W, 88.2 m.

Location description: in van, small buildings, hill to one side.

Location identification: #12, 1350-2 and 1410-2, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	0%	86.7%	**100%**
	Mean Error [m]	-	532.5	**487.3**
	1 Sigma (67%) Error [m]	-	566.6 (58%)	**546.2**
With Salt Head 30 samples	Yield	0%	23.3%	**100%**
	Mean Error [m]	-	260.2	**239.2**
	1 Sigma (67%) Error [m]	-	354.6 (16%)	**243.4**

Figure 8 Location #12

3.8 R Parking Lot

Reference location (LLH): 32° 54.2060' N, 117° 12.1058' W, 96.7 m.

Location description: in van, facing canyon, 4 storey building behind.

Location identification: #13, 1430-2 and 1450-2, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head	Yield	23.3%	96.7%	**100%**
	Mean Error [m]	669.33	196.6	**247.9**
30 samples	1 Sigma (67%) Error [m]	800.8 (16%)	201.1 (65%)	**209.2**
With Salt Head	Yield	0%	90%	**100%**
	Mean Error [m]	-	233.4	**229.6**
30 samples	1 Sigma (67%) Error [m]	-	262.8 (60%)	**261.5**

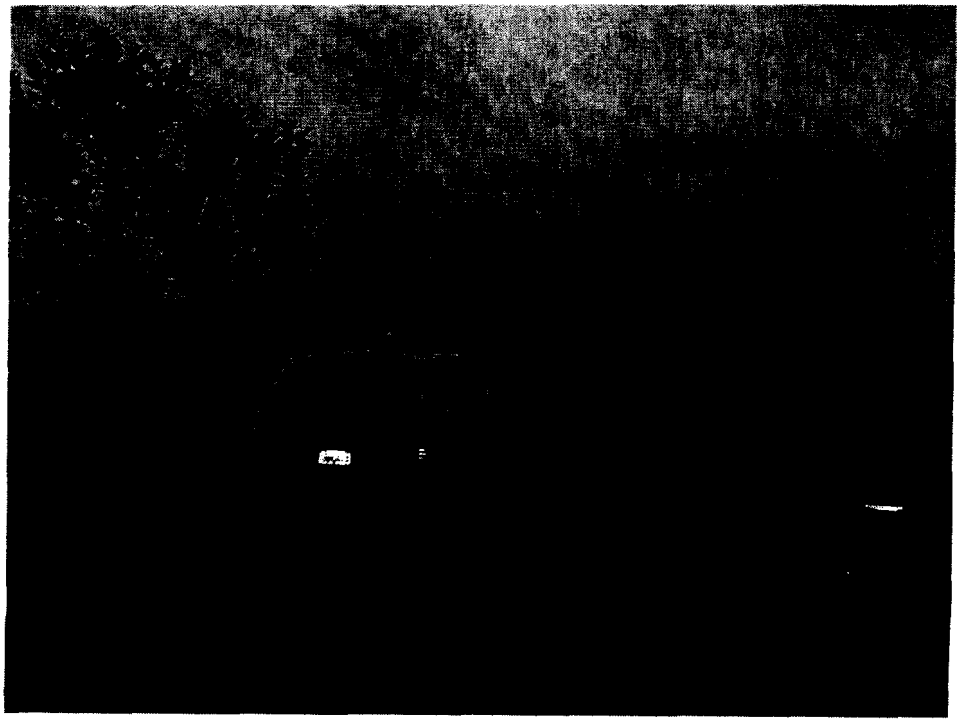

Figure 9 Location #13

3.9 Amatos, Sorrento Valley

Reference location (LLH): 32° 54.1099' N, 117° 13.3561' W, 13.2 m.

Location description: in van, in the canyon with highway to one side, small buildings in vicinity.

Location identification: #16, 1200-2 and 1210-2, 22 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	0%	90%	**100%**
	Mean Error [m]	-	668.5	**669.7**
	1 Sigma (67%) Error [m]	-	737.4 (60%)	**715.4**
With Salt Head 30 samples	Yield	6.7%	86.7%	**100%**
	Mean Error [m]	291.4	543.5	**564.7**
	1 Sigma (67%) Error [m]	317.7 (4%)	659.9 (58%)	**674.7**

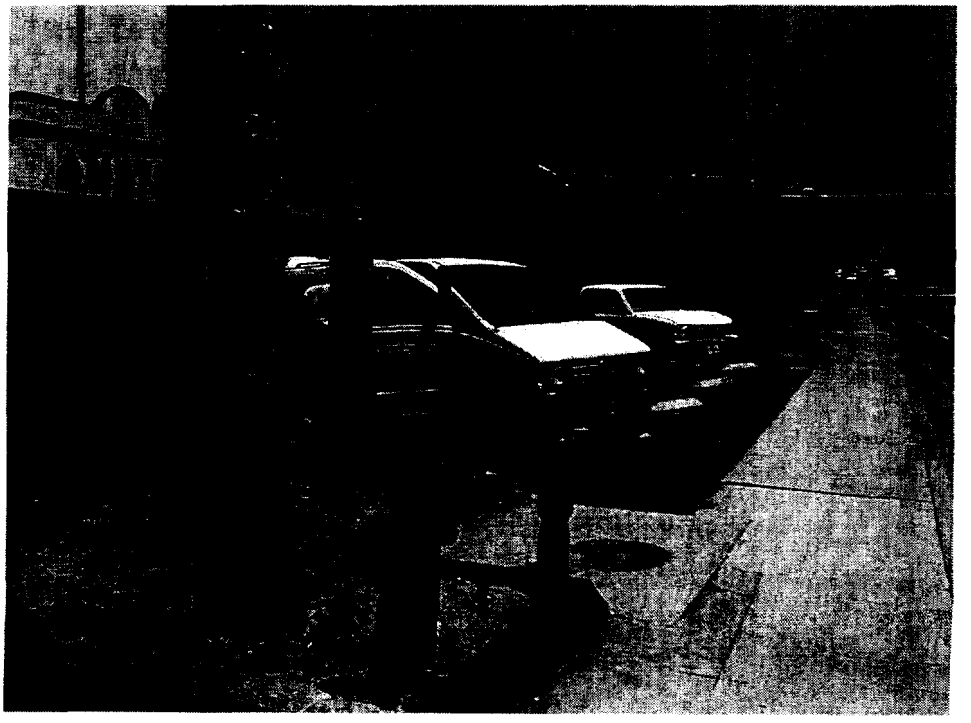

Figure 10 Location #16

3.10 UCSD Information Booth

Reference location (LLH): 32° 53.3137' N, 117° 14.4576' W, 133.1 m.

Location description: in van, near trees.

Location identification: #17, 1410-2 and 1420-2, 22 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	93.3%	100%	**100%**
	Mean Error [m]	199.5	95.7	**95.7**
	1 Sigma (67%) Error [m]	271.4 (63%)	117.5	**117.5**
With Salt Head 30 samples	Yield	90%	100%	**100%**
	Mean Error [m]	169.4	153.7	**153.7**
	1 Sigma (67%) Error [m]	181.1 (60%)	122.2	**122.2**

4 Indoor Locations

Indoor locations were done in Qualcomm's buildings. The general characteristics of these buildings are: concrete with shaded glass windows and dry wall interior. For each location 2 sets of test were done, one without and one with the "salt head" close to the phone.

Reference location is given in LLH, latitude (in degrees and minutes), longitude (in degrees and minutes) and height (in meters) coordinates using WGS-84.

4.1 AA-3170

Reference location (LLH): 32° 53.4405' N, 117° 13.4029' W, 106 m.

Location description: third floor window office of 4 floor building, facing south.

Location identification: #1, 1035-7 and 1100-2, 20 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	93.3%	100%	**100%**
	Mean Error [m]	176.2	149.4	**149.4**
	1 Sigma (67%) Error [m]	198.6 (63%)	166.0	**166.0**
With Salt Head 30 samples	Yield	100%	100%	**100%**
	Mean Error [m]	178.4	158.9	**158.9**
	1 Sigma (67%) Error [m]	209.0	176.3	**176.3**

Figure 11 Location #1

4.2 AA-117C

Location description: ground floor internal office of 4 floor building.

Results: we were not able to setup a call.

4.3 AA-225

Reference location (LLH): 32° 53.4423' N, 117° 13.3883' W, 103 m.

Location description: second floor foyer above lobby of 4 floor building, lots of windows, facing south.

Location identification: #2, 1020-2 and 1130-2, 20 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	86.7%	100%	**100%**
	Mean Error [m]	135.1	121.2	**121.2**
	1 Sigma (67%) Error [m]	167.7 (58%)	127.0	**127.0**
With Salt Head 30 samples	Yield	83.3%	96.7%	**100%**
	Mean Error [m]	97.7	98.7	**104.7**
	1 Sigma (67%) Error [m]	110.4 (56%)	107.0 (65%)	**113.0**

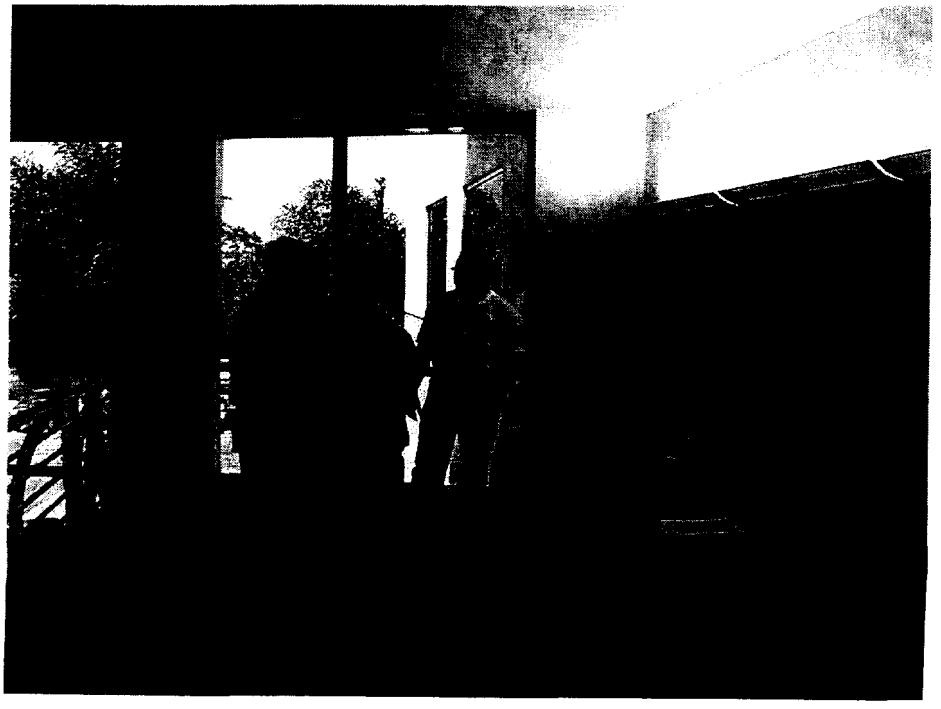

Figure 12 Location #2

4.4 L – Lobby #1

Reference location (LLH): 32° 53.7011' N, 117° 11.7248' W, 108 m.

Location description: lobby on table near widows facing north-west, ground (first) floor of 7 story building.

Location identification: #8, 1035-7 and 1055-7, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	13.3%	83.3%	**100%**
	Mean Error [m]	402.6	422.6	**478.3**
	1 Sigma (67%) Error [m]	393.0 (9%)	432.3 (56%)	**662.4**
With Salt Head 30 samples	Yield	3.3%	86.7%	**100%**
	Mean Error [m]	1751.2	294.3	**356.6**
	1 Sigma (67%) Error [m]	1751.2 (2%)	349.2 (58%)	**373.3**

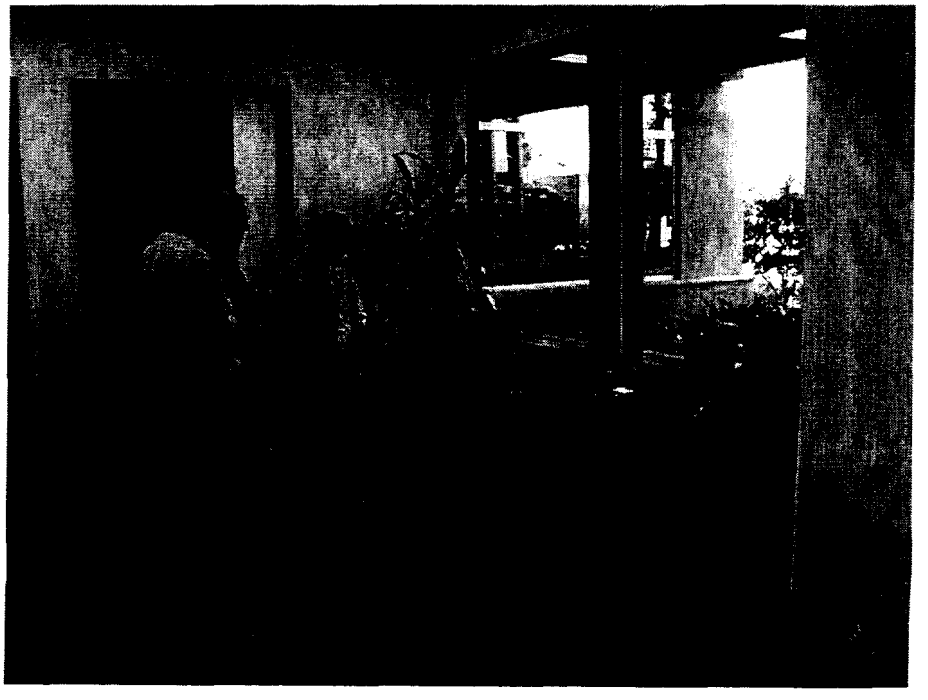

Figure 13 Location #8

4.5 L – Lobby #2

Reference location (LLH): 32° 53.6981' N, 117° 11.7268' W, 108 m.

Location description: lobby on cart near receptionist, large windows several meters away, ground (first) floor of 7 story building.

Location identification: #9, 1120-2 and 1120-2, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	80%	73.3%	**100%**
	Mean Error [m]	290.8	240.2	**379.8**
	1 Sigma (67%) Error [m]	276.4 (54%)	255.2 (49%)	**425.1**
With Salt Head 10 samples	Yield	30%	90%	**100%**
	Mean Error [m]	325.8	211.1	**268.1**
	1 Sigma (67%) Error [m]	618.1 (20%)	272.3 (60%)	**272.3**

Note: only 10 measurements we taken with the salt head, due to the call dropping.

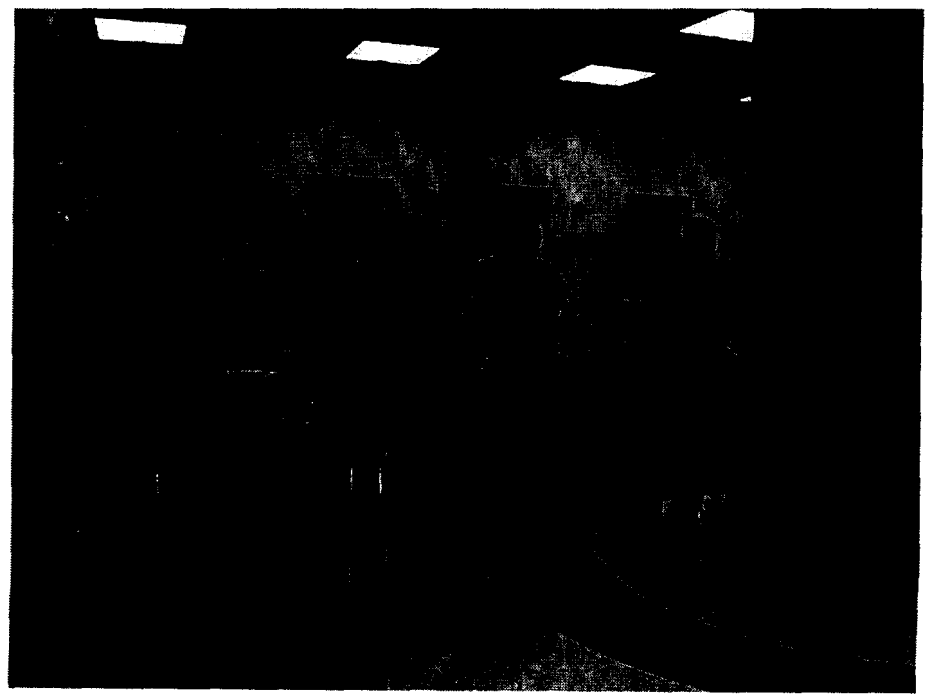

Figure 14 Location #9

4.6 L501C

Reference location (LLH): 32° 53.7050' N, 117° 11.7405' W, x122 m.

Location description: inner location on fifth floor of 7 story building.

Location identification: #10, 1140-2 and 1200-2, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	100%	93.3%	**100%**
	Mean Error [m]	74.2	71.8	**137.2**
	1 Sigma (67%) Error [m]	66.3	81.3 (63%)	**82.9**
With Salt Head 30 samples	Yield	100%	100%	**100%**
	Mean Error [m]	82.5	86.9	**86.9**
	1 Sigma (67%) Error [m]	75.9	106.3	**106.3**

Figure 15 Location #10

4.7 R Library

Reference location (LLH): 32° 54.2740' N, 117° 12.1155' W, 105 m.

Location description: on counter near window, ground floor of 4 story building.

Location identification: #14, 1520-2 and 1540-2, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	0%	0%	**100%**
	Mean Error [m]	-	-	**205.2**
	1 Sigma (67%) Error [m]	-	-	**215.0**
With Salt Head 30 samples	Yield	0%	0%	**100%**
	Mean Error [m]	-	-	**203.5**
	1 Sigma (67%) Error [m]	-	-	**210.9**

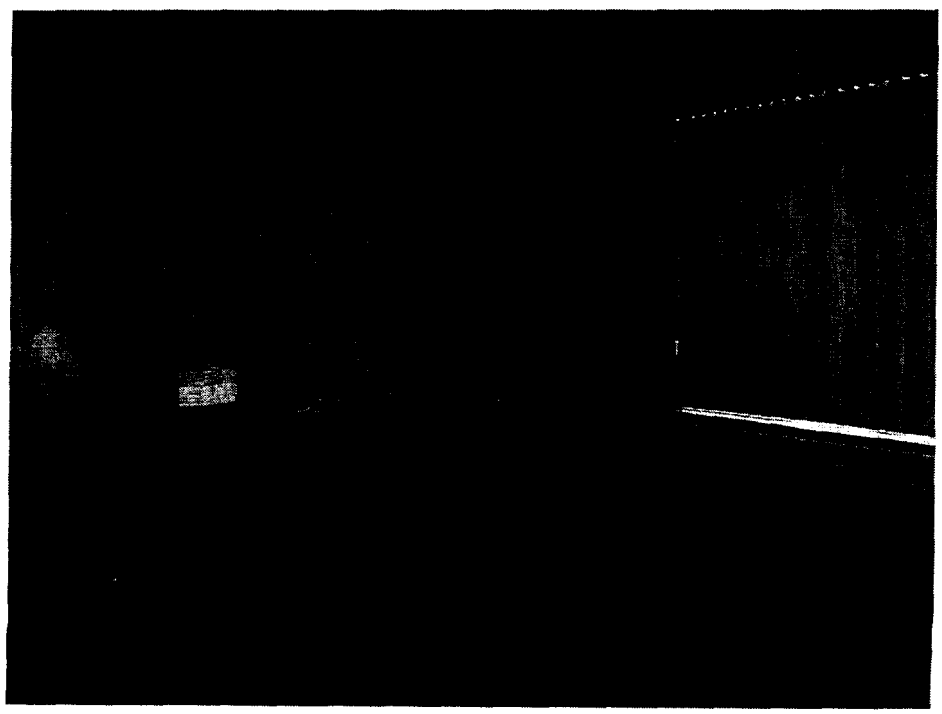

Figure 16 Location #14

4.8 R 214

Reference location (LLH): 32° 54.2684' N, 117° 12.1290' W, 108 m.

Location description: conference room counter, second floor of 4 story building.

Location identification: #15, 1600-2 and 1610-2, 21 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 30 samples	Yield	0%	0%	**100%**
	Mean Error [m]	-	-	**195.4**
	1 Sigma (67%) Error [m]	-	-	**212.8**
With Salt Head 30 samples	Yield	0%	0%	**100%**
	Mean Error [m]	-	-	**201.8**
	1 Sigma (67%) Error [m]	-	-	**209.7**

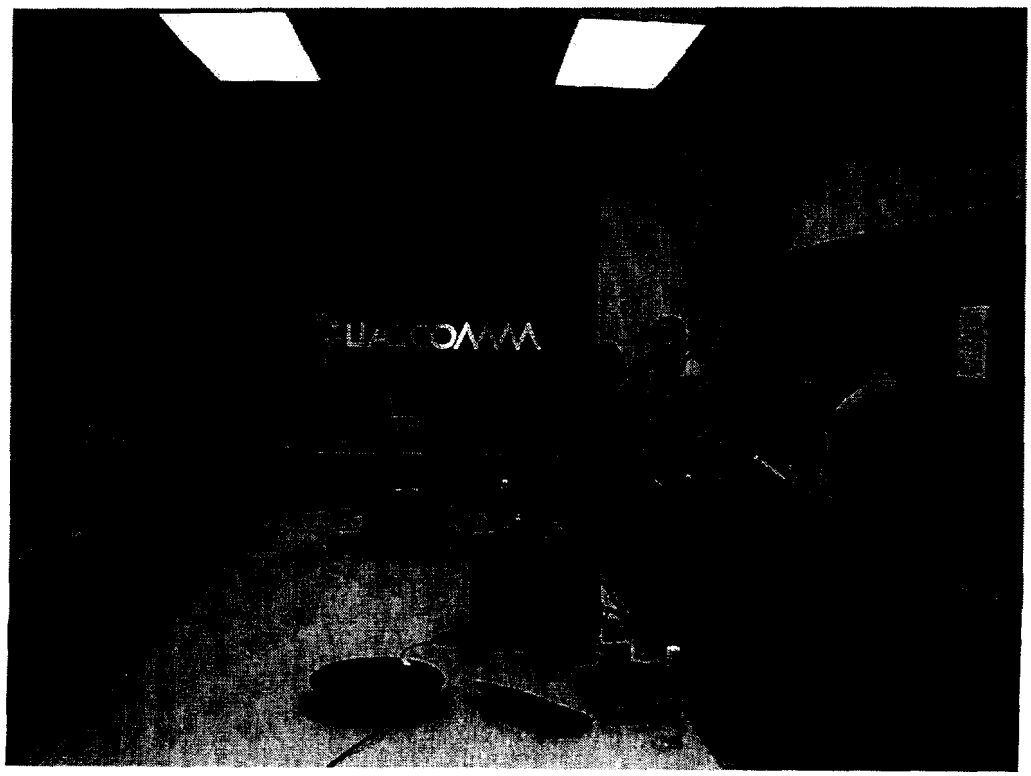

Figure 17 Location #15

5 Moving Test - I-5 South from Sorrento Valley Rd.

Only one moving test was performed. Data started to log about 7.5 seconds after the starting point.

Location description: highway I-5, 5 going south from the Sorrento Valley Rd. interchange to the Genesse interchange.

Speed: 60 mph.

Start point (LLH): 32° 53.2337' N, 117° 13.6738' W, 83.5 m.

End point (LLH): 32° 52.3127' N, 117° 13.76454' W, 89.6 m.

Location identification: 0945-54, 22 June, 2000.

Results:

		TDOA Only	TDOA + Fake RTD	TDOA, Fake RTD + AOA Estimation
No Salt Head 10 samples	Yield	0%	0%	**100%**
	Mean Error [m]	-	-	**162**
	1 Sigma (67%) Error [m]	-	-	**180**

Only one BTS was seen (16,152), and the drive was passing close to the BTS. The above estimate was taken to the position that was roughly half the time (2.5 sec) into the logging. Note that the speed is on the order of 27 m/sec.

6 Summary

6.1 Results of Salt Head vs. No Salt Head

Testing with the salt head sometimes improved the results and sometimes hurt the results. A possible explanation is that on occasion it could attenuate the strong signal, effecting the AGC level of the phone, and allowing weaker signals to be detected. These measurements contribute to the solution to produce a better result. On other occasions, it could attenuate the weaker signals, making them not detectable, and thus degrading the solution.

6.2 General Summary

This data collection includes a random number of locations selected in an area around the Qualcomm campus in San Diego. Data analyses reflects current status of algorithms and includes assumptions as described in Chapter 2. These AFLT based solutions are not mature, so some improvements are possible. In addition, caution must be exercised in interpreting the statistical results as explained in Section 2.3.

AFLT based algorithms pose a number of inherent challenges, which cause results to vary even within the same physical environment (urban, sub-urban, rural etc.). In this environment, the results can vary significantly. These challenges include dependency on cell geometry, multipath (or excess delay) variations and the near-far problem (where because we receive one BTS's signals too strong, we are not able to receive signals from other BTSs).

For other environments and areas with different network planning, the results may significantly differ. Characteristics of these differences can cause the results to change both for good and for worse. More testing in varied environments is required to fully characterize the performance.